

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of : Customer Number: 45462
Deyang Hou, :
Application No. 10/597,000; : Group Art Unit: 3752;

Filed: June 12, 2008 : Examiner: JONAITIS, JUSTIN

For: MIXED-MODE FUEL INJECTOR WITH A VARIABLE ORIFICE

PATENT APPLICANT'S APPEAL BRIEF AND AMENDMENTS IN RESPONSE TO
OFFICE ACTION

Mail Stop Inter Partes Reexam
Attn: Central Reexamination Unit
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

INTRODUCTORY COMMENTS

In response to the Office Action dated November 22, 2010, for patent application No. 10/597,000, please amend the above-identified U.S. patent application as follows:

Listing of the Claims are reflected in the listing of claims which begins on page 2 of this paper. This listing of claims will replace all prior versions, and listings of claims in the application. No new matter was added. Claims 11, 12, 17, 19, 20, 21, and 22 were cancelled.

Description begins on page 6 of this paper. This Description will replace the **Description** in the application. No new matter has been added. Only brief description for FIG. 5 to 10 was added in response to Examiner's suggestions.

Amendments to the Drawings begin on page 15 of this paper. This 'Drawings' will replace all prior versions, and **Drawings** in the application. FIG. 5 to 10 was added in response to Examiner's suggestions for illustrating every feature in the claims.

Appeal Brief begins on page 23 of this paper.

Claims

1. (Previously presented) A mixed-mode fuel injector comprising:
 - (i) a nozzle body (5) comprising passages for fuel (FP), an inner cylindrical space for receiving a needle valve (1), and a conical surface (C) close to the tip (7) of the nozzle body for guiding a spray of fuel;
 - (ii) a needle valve (1), which has a converging-diverging conical head for guiding a spray of fuel and which is movable back and forth and received in said nozzle body, wherein said needle valve is at a biased closing position with its seal surface (2) being pressed against nozzle body (5) to block fuel flow, or an opening position defined by driving means through lifting the said needle valve seal surface away from nozzle body; and
 - (iii) a micro-variable-circular-orifice comprising a variable annular ring aperture (4) between said needle valve and said nozzle body which has means of producing hollow conical spray, and at least one conventional multijet-orifice (6) inside the said nozzle body (5) which has means of producing at least one conventional jet spray, such that fuel is dischargeable in variable sprays of hollow conical and multiple jets shapes through said micro-variable-circular-orifice and multijet-orifice by lifting said needle valve at different magnitudes.
2. (Previously presented) A mixed-mode fuel injector according claim 1, wherein the micro-variable-circular-orifice further comprises a plurality of multijet-orifices (6).
3. (Previously presented) A mixed-mode fuel injector according to claim 1 or 2, wherein the conical surface (C) has a single conical surface.
4. (Previously presented) A mixed-mode fuel injector according to claim 1 or 2, wherein the conical surface (C) is an integrated conical surface having two or more conical surfaces with different conical angles connected together.
5. (Previously presented) A mixed-mode fuel injector according to claim 1 or 2, wherein the conical surface (C) is a diverging curved surface.
6. (Previously presented) A mixed-mode fuel injector according to claim 1 or 2, wherein the needle lift for the opening position is approximately in the range of 0-300 μ m, the needle head diameter is approximately in the range of 0.8-3.5mm, and the angle between the centerline of the nozzle body (5) and the inner conical surface (C) at the nozzle body tip (7) is approximately in the range of 35-75 degree.

7. (Previously presented) A mixed-mode fuel injector according to claim 2, wherein the plurality of multijet-orifices (6) is on the said conical surface (C) with cross sections that are one or more of semi-circles, arcs, triangles, trapezoids or other polygons.

8. (Previously presented) A mixed-mode fuel injector according to claim 2, wherein the needle head (3) remains at least partially received within the tip (7) as the needle valve (1) is moved back and forth between the biased closing position and opening position such that when fuel is injected through the micro variable aperture (4) between the needle head and said conical surface of the nozzle body, fuel is also injected through the multijet-orifices (6), the upper surface of the needle head and the conical surface serve as guiding surfaces for fuel sprays.

9. (Previously presented) A mixed-mode fuel injector according to claim 7, wherein there are about 4-20 multijet-orifices with the cross-section of semi-circles with the diameters approximately in the range of 50-300 μ m.

10. (Previously presented) A mixed-mode fuel injector according to claim 7, wherein there are about 4-20 multijet-orifices (6) having a cross-section other than semi-circles with the maximum dimension approximately between 50-400 μ m.

11. (Cancelled) A mixed-mode fuel injector according to any of *claims 2 to 10*, wherein the sizes of said multijet-orifices (6) are the same.

12. (Cancelled) A mixed-mode fuel injector according to any of *claims 2 to 10*, wherein the sizes of the multijet-orifices (6) are different depending on specific needs of atomization.

13. (Currently amended) A mixed-mode fuel injector according to *claim 2*, wherein the said multijet-orifices (6) are distributed on or under the conical surface (C) so that they can be open channels or closed channels.

14. (Previously presented) A mixed-mode fuel injector according to claim 2, has a plurality of multijet-orifices underneath the said conical surface (C), forming a sac-hole or valve-covered-orifice multi-hole type injector through blocking the circular aperture by the needle head at a predefined needle-lift range.

15. (Previously presented) A mixed-mode fuel injector according to claim 2, wherein different shapes of fuel sprays are generated by changing the magnitude of lift of said needle

valve (1) and the needle valve is arranged within the nozzle body (5) so that, at low to medium injection loads, fuel is mainly injected through the variable circular aperture between the needle head (3) and conical surface (C) of nozzle body (5) by a small needle lift, thus mainly forms a conical shape spray, while at high injection loads, fuel is injected through both the variable circular aperture between the needle head and nozzle body and the multijet-orifices (6) by a larger needle lift, thus forms a mixed-mode conical-multi-jet shape spray, whereby provides different atomization desired by engine combustion at different loads.

16. (Previously presented) A mixed-mode fuel injector according to claim 2, wherein different shapes of fuel sprays are generated by changing the magnitude of lift of said needle valve (1) and the needle valve is arranged within the nozzle body (5) so that, at low to medium injection loads, fuel is mainly injected through the variable circular aperture between the needle head (3) and conical surface (C) of nozzle body by a small needle lift, thus mainly forms a conical shape spray, while at high injection loads, the needle head can completely or partially block the variable circular aperture by a large needle lift, whereby fuel is fully or mainly injected through the multijet-orifices (6), which can be open channels or closed channels depending on penetration needs, thus mainly forms conventional multi-jet sprays at high loads, whereby provides different penetration desired by engine combustion at different loads.

17. (Cancelled) A mixed-mode fuel injector according to claim 1 or 2, wherein the fuel channel between the needle valve (1) and the nozzle body (5) is of converging-diverging shape and by lifting said needle valve at different magnitudes, the minimum cross-section is at the sealing surface (2) during the early stage of fuel injection, the minimum cross-section is at said micro-variable-circular-orifice or at the sealing surface (2) during the middle stage of fuel injection, and the minimum cross-section is at the sealing surface (2) again during the late stage of fuel injection, whereby it has means of ensuring fine atomization during all fuel injection stages.

18. (Previously presented) A mixed-mode fuel injector according to claim 1 or 2, wherein the angle between the centerline of the conical surface (C) and the centerline of the nozzle body (5) is approximately 0-15 degrees, depending on an angle between a centerline of the fuel injector and a centerline of a piston in an engine cylinder.

19. (Cancelled) A mixed-mode fuel injector according to any of the preceding claims, wherein the fuel injected is one or more of diesel fuels, gasoline fuels, alternative fuels, mixtures of water and fuels, pure water or liquid exhaust cleaning additives wherein the fuel injector is a general purpose injector.

20. (Cancelled) A mixed-mode fuel injector according to claim 1, wherein the needle valve (1) is passively driven by high fuel pressure which provides said driving means.

21. (Cancelled) A mixed-mode fuel injector according to claim 1, wherein the needle valve (1) is actively driven by an actuator which provides said driving means.

22. (Cancelled) A mixed-mode fuel injector according to claim 21, wherein the actuator is a solenoid or a piezo actuator.

23. (Previously presented) A mixed-mode fuel injector, which has a micro-variable-circular-orifice (MVCO) comprising a variable annular ring aperture as in claim 1, wherein the MVCO is used as a sole orifice or in-combination with other multi-hole conventional orifice wherein fuel is injected through multiple channels in multi-jets into combustion chamber.

MIXED-MODE FUEL INJECTOR WITH A VARIABLE ORIFICE

DESCRIPTION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a U.S. National Stage of International Application No. PCT/IB2005/051474, filed May 5, 2005, which claims the benefit of U.S. Provisional Application No. 60/594,110, filed Mar. 11, 2005.

BACKGROUND OF THE INVENTION

1. Field of the Invention - The invention relates to a mixed-mode fuel injector with a micro-variable-circular-orifice (MVCO) and homogeneous atomization, and particularly to a fuel injector for a direct injection internal combustion engine, which can be either a spark-ignition gasoline engine or a compression-ignition diesel engine. The current filing is focused on the nozzle part of the fuel injector.

2. Description of the Related Art - The combustion process in a conventional direct injection Diesel engine is characterized by diffusion combustion with a multi-hole fuel injector. Due to its intrinsic non-homogeneous characteristics of fuel-air mixture formation, it is often contradictory to simultaneously reduce soot and NO_x formation in a conventional diesel engine. Over last two decades, significant progress has been made for Diesel engine combustion (United States Patents No. 4,779,587, 6,230,683), but further reducing emissions from Diesel engines to comply upcoming emission legislations still remains a challenge. Progress has been made in recent years for research of Homogeneous-Charge Compression-Ignition (HCCI) combustion engines. However, many issues remain to be solved to have a practical approach to control the ignition timing, the duration of combustion, the rate of combustion for HCCI engine for various load conditions. Current engine control strategies, such as US Patent No. 6,230,683, are effective but very complex and will increase the cost for applications. It seems more a viable solution to operate engine in a mixed-mode, or in HCCI mode or quasi-HCCI mode at low to medium loads, and in conventional spray combustion mode at high loads for the near future. It would be desirable to design a fuel injector which is suitable for this

type of mixed-mode combustion, at least to provide most features desired by optimal engine combustion.

To improve combustion at the full load range, fine atomization with accurate control of doses and timing is needed. A well-known current art for improving atomization is to increase the number of holes of nozzles and decrease the diameter of nozzle holes, and use piezo actuators and high common rail pressure (United States Patents 6,726,121, 6,557,779), such as BOSCH's piezo-injector with coaxial-vario-nozzle (Roger Busch, Advanced Diesel Common Rail Injection System for Future Emission Legislation, Diesel Engine Emission Reduction Conference, Aug., 2004, Coronado, California). Such an approach, while it's effective for improving atomization and combustion, it does, at the same time, mandate a very complex structure and a much higher rail pressure, thus increase the power needed for fuel pump and manufacture cost of fuel systems, and increase the potential risks of fuel leaking.

3. Objectives and Advantages – Accordingly, several objectives and advantages of the invention are: (1) the micro-variable-circular-orifice (MVCO) is equivalent to a connection of infinite number of micro-holes, thus said fuel injector can form a variable micro aperture for fine atomization and ensure high fuel injection rate simultaneously. It enables using a single needle valve with micro lift, which is desired for working with a piezo actuator or hydraulic pressure amplifier to accurately control the fuel injection dose, atomization quality and give a much shorter response time. (2) said fuel injector, through its variable nature of injection sprays, provides a homogeneous fine atomization at low to medium loads, thus it is favorable for HCCI combustion mode, and provides fine atomization and sufficient penetration at high engine loads, thus it ensures engine power output. The varying micro-variable-circular-orifice (MVCO) feature can provide different sizes of the fuel injection exit cross-section area of the injector, which is superior to a conventional nozzle with fixed injection hole cross-section area, thus said MVCO can provide different fuel atomization rate and SMD (Sauter Mean Diameter) based on needs for optimal combustion for different load and speed conditions. (3) Since the micro-variable-circular-orifice (MVCO) keeps varying during the fuel injection process, the needle valve has self-cleaning effect, it is more robust for eliminating

clogging. This feature improves reliability of fuel injection systems, it has more advantages than a conventional multi-hole nozzle, which is prone to get clogged in certain operating conditions and has heavy injection pressure loss when injection holes are too small. (4) The special design of the flow channel in the injector reduces pressure loss comparing with a conventional multi-hole nozzle through its novel fuel passage design near the MVCO, thus reduces the demand for extremely high rail pressure as required by small multi-hole nozzle, and reduces required fuel pump power. (5) Given many desirable features for combustion, said fuel injector also has a relatively simple structure, instead of a complex structure with two needle valves, it uses a single needle valve to generate mixed-mode sprays through novel orifice design. It can save manufacturing cost. Said fuel injector provides a key device for meeting the current and future engine emission regulations.

SUMMARY OF THE INVENTION

This invention provides a novel design of a mixed-mode fuel injector for mixed-mode HCCI-conventional combustion, more specifically a novel nozzle with a micro variable circular aperture and multijet-orifices to reduce pressure loss in the injector channel and provide a homogeneous initial fuel distribution. The mixed-mode fuel injector can generate a homogeneous fine atomization with sufficient penetration without relying on excessive high rail pressure. The fuel injector is a high-accuracy couple of components with a needle valve and a nozzle body, which system has a micro-variable-circular-orifice (MVCO) comprising a variable circular aperture between needle valve and nozzle body and multijet-orifices on the inner conical surface closing to the nozzle body tip. The fuel injector is capable of generating variable mixed-mode sprays of conical and multi-jet shapes, with a major circularly homogeneous conical spray at low to medium engine loads, and mixed-mode sprays composed of a conical spray and multi-jets at high loads. The mixed-mode-spray ensures homogeneous atomization and sufficient penetration simultaneously.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary sectional view of a first exemplary embodiment of an injector of the invention;

FIG. 2 is an amplified fragmentary sectional view of FIG. 1 for the micro-variable-circular-orifice (MVCO);

FIG. 3 is a three dimensional view of Fig. 1. (a) needle valve only (1); (b) nozzle body (5) only; (c) assembly of needle valve (1) and nozzle body (5);

FIG. 4 is an illustration of the mixed-mode conical-multi-jet spray generated by the embodiment of the fuel injector illustrated in FIG. 1;

FIG. 5 is an illustration of the conical surface (C) with 2 conical surfaces;

FIG. 6 is an illustration of the conical surface (C) being different shapes of diverging curve surfaces;

FIG. 7 is an illustration of plurality of multijet orifices being on the conical surface as well as the various multijet orifice types (semi-circular, arcs, triangles, trapezoids, etc);

FIG. 8 is an illustration for multijet orifices (6) being distributed 'on' or 'under' the conical surface (C) so that they can be closed channels , as shown in FIG 8 (a), or open channels, as shown in FIG. 8 (b),

FIG. 9 is an illustration of the variable circular aperture, as shown in FIG. 9 (a).The diagrams of flow during a low to medium load with small needle lift is shown in FIG. 9 (a), and flow during a high load with large needle lift is shown in FIG. 9 (b).

FIG. 10 The diagram of a mixed-mode fuel injector having a plurality of multijet-orifices underneath the conical surface (C), forming a sac-hole orifice (FIG. 10a) at its opening position, or valve-covered-orifice multi-hole type (FIG. 10c) at its opening position, through blocking the circular aperture by the needle head at a predefined needle-lift range. FIG.10 (b) shows the sac-hole orifice injector at its seating position, FIG 10 (d) shows the valve-covered-orifice multi-hole injector at its seating position.

In all the figures, 1 – needle valve; 2 - needle sealing surface; 3 - needle head; 4 – micro-variable-circular-orifice (MVCO) (including a annular aperture formed by said needle and said nozzle body); 5 - nozzle body; 6 – *multijet orifices*; 7 - tip surface of the nozzle body; A - up-rim of the needle head; B - the intersection of the needle head outer surface (or its extension) and tip surface of nozzle body; C - conical surface at the tip surface of the nozzle body; D - inner hole of the tip of the nozzle body; F – driving means, which can be active means provided by solenoid or piezo actuators, or a passive means by fuel pressure; S – high pressure fuel supply.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The mixed-mode fuel injector is a high-accuracy couple of components with a needle valve (1 in FIG. 2), which has a conical head for guiding fuel sprays, which has an opening and a biased closing position, which is movable back and forth and received in a nozzle body (5 in FIG. 2). The fuel injector has a micro-variable-circular-orifice (MVCO) (FIG. 2) comprising of a variable annular ring aperture (4) between said needle valve (1) and said nozzle body (5) and multijet-orifices (6) inside the nozzle body (5) closing to the nozzle body tip (FIG.1, FIG.2, FIG. 3). Said needle valve is received in said nozzle body and has a biased closing position and an opening position decided by driving means such as actuators. When said needle valve is at its opening positions, fuel is discharged through said orifices. *By lifting the said needle valve at predefined magnitudes, the needle valve can partially or completely block the annular aperture (4), thus fuel can be injected as hollow conical spray through the annular aperture at small needle lift or conventional multijet sprays through the multijet-orifices when the needle head blocks the annular aperture (4) at large needle lift.* The fuel injector is capable of generating variable mixed-mode sprays of conical and multi-jet shapes (FIG. 4), whereby generating a major circularly homogeneous conical spray at low to medium loads, and variable mixed-mode fuel sprays at high loads to ensure homogeneous atomization and sufficient penetration. Depending on the location of the multijet-orifices and whether the multijet-orifices are open channels or closed channels simply like conventional nozzle-holes, it

can form different versions of spray shapes to satisfy different needs of penetration and atomization.

The mixed-mode fuel injector, wherein the needle lift is micro-motion with a range approximately 0-300 μ m, the included angle of the conical sealing surface (2) at the nozzle body is approximately between 50-70 degree, the needle head diameter (d_3) is between 0.8-3.5mm, the angle between the centerline of the nozzle body and the inner conical surface (C) at the nozzle body tip is approximately in the range of 35-75 degree. A fuel injector, as a simplified version or alternative of said mixed-mode fuel injector (FIG. 2), wherein close to the tip surface (7) of nozzle body there is a conical surface (C), which is a smooth surface, the conical surface can be a single conical surface, or can be an integrated conical surface comprising two or more conical surfaces with different conical angles, or a diverging curve surface, the upper rim (A) of the needle head (3) is merged in the tip surface (7) of the nozzle body during the needle lifting, the needle head (3) can be partially or wholly merged in the tip surface (7) of the nozzle body during the needle lifting. When the needle valve is lifted, fuel is injected through the aperture (4) between the needle head and conical surface (C) of the nozzle body.

The mixed-mode fuel injector (FIG. 2), wherein close to the tip surface (7) of nozzle body there is a conical surface (C), the conical surface can be a single conical surface, or can be an integrated conical surface comprising two or more conical surfaces with different conical angles, or a diverging curve surface, the conical surface close to the needle valve is a surface with multijet-orifices (6) with the shape of semi-circle, arcs, triangle, trapezoid or other polygons, or with helical multijet-orifices, the upper rim (A) of the needle head (3) is merged in the tip surface (7) of the nozzle body (5) during the needle lifting, the needle head can be partially or wholly merged in the tip surface (7) of the nozzle body during the needle lifting, when the needle valve is lifted, fuel is injected through the variable aperture between the needle head and conical surface (C) of the nozzle body, fuel is also injected through the multijet-orifices (6). The upper surface of the needle head (3) and the conical surface (C) serves as guiding surfaces for sprays.

The mixed-mode fuel injector, wherein the fuel channel between the needle head (3) and conical surface (C) of the nozzle body is of converging-diverging nozzle shape, due to micro-needle-lift of the needle valve, the lifted minimum dimension of the aperture of the channel is approximately in the range of 30-125 μm , the minimum aperture is at the sealing surface (2) during the early stage of fuel injection. The minimum aperture is at the needle valve exit injection-cross-section (4) or at the sealing surface (2), depending on a specific design, during the middle stage of fuel injection, and the minimum aperture is at the sealing surface again during the late stage of fuel injection. During all fuel injection stages, the minimum aperture is approximately less than 125 μm , thus ensures fine atomization during all fuel injection stages.

The mixed-mode fuel injector, wherein the depth of conical surface (C) close to the nozzle exit is approximately in the range of 0.15-3mm, the conical angle of conical surface (C) is approximately in the range of 80-150 degree.

The mixed-mode fuel injector (FIG. 1, FIG.2), wherein there are approximately 4-20 multijet-orifices (6) with the cross-section shape of either semi-holes with the diameters approximately in the range of 50-300 μm , or other shapes as described above with the maximum dimension approximately between 50-400 μm (i.e., the geometric cross section of such a channel can fit in a circle with a diameter of 50-400 μm), the sizes of these multijet-orifices can be the same or varying depending on specific needs of atomization, these multijet-orifices can be homogeneously or non-homogeneously distributed on the conical surface(C).

The mixed-mode fuel injector, wherein at low to medium engine loads, fuel is mainly injected through the variable circular aperture between said needle head and said nozzle body, thus mainly forms a conical shape spray, while at high loads, fuel is injected through both the variable circular aperture and the multijet-orifices (6) on the conical surface(C), fuel forms mixed-mode conical-multi-jet shape sprays (FIG. 4), thus ensures both fine atomization and sufficient penetration.

A special version of fuel injector as described above has means of generating different shapes of fuel sprays by changing the magnitude of lift of said needle valve, wherein at low to medium injection loads, fuel is mainly injected through the variable circular aperture between the needle head and nozzle body, thus mainly forms a conical shape spray, while at high injection loads, the needle head can completely or partially block the variable circular aperture, whereby fuel is fully or mainly injected through the multijet-orifices, which can be open channels or closed channels depending on penetration needs, thus mainly forms conventional multi-hole sprays at high loads, whereby provides different penetration desired by engine combustion at different loads.

A special version of fuel injector as described above has a plurality of multijet-orifices underneath the said conical surface with the cross section shape of conventional nozzle holes, which can form sac-hole or valve-covered-orifice multi-hole type injector through blocking the circular aperture by the needle head at a predefined needle-lift range.

The mixed-mode fuel injector, wherein the angle between the centerline of the conical surface (C) and the centerline of the nozzle body (5) is approximately between 0-15 degree, depending on the angle between the centerline of the fuel injector and the centerline of the piston in the engine cylinder.

The mixed-mode fuel injector, is intended but not limited to direct injection diesel engines, direct injection gasoline engines, or other direct injection alternative fuel engines, it is intended for mechanical, electro-mechanical, piezo fuel injectors, or fuel injectors with hydraulic pressure amplifiers. Said fuel injector can also be used to inject other liquids, such as water, thus it can be used as a general purpose injector.

For small direct injection diesel engines, the major dimensions for the mixed-mode fuel injector are approximately: $d_1 = 3.0 - 5 \text{ mm}$; $d_1 - d_2 = 0.3 - 0.8 \text{ mm}$; $d_3 = 0.8 - 2.5 \text{ mm}$; the diameter of nozzle body hole – $d_3 = 10 - 18 \text{ }\mu\text{m}$; the included angle at sealing surface at nozzle body = 50 - 75degree; the needle-lift range = 30 - 240 μm ; the cone angle of the conical surface at the tip of nozzle body = 100 - 150 degree; the number of micro channels on the conical surface (C) = 6 - 18; the maximum dimension of the micro channels (6) = 50 - 280 μm .

For medium size direct injection diesel engines, the major dimensions for the mixed-mode fuel injectors are: $d_1 = 4 - 6 \text{ mm}$; $d_1 - d_2 = 0.4 - 0.8 \text{ mm}$; $d_3 = 1.0 - 3.0 \text{ mm}$. The cone angle of the conical surface (C) = 120 - 150 degree; the maximum dimension of the micro channels (6) = 50 - 400 μm ; other parameters are similar to small diesel engines. The rail pressure for said mixed-mode fuel injector is about 800 - 1200 bar. While higher pressure is better, it is not mandated for fine atomization. The open injection pressure is approximately 240 bar or higher.

The mixed-mode fuel injector is intended for but not limited to internal combustion engines. The outer surface of the nozzle body can be of cylindrical, conical, or converging-diverging shape.

Those who are skilled in the art will find that it's easy to make minor changes to the nozzle structure following the same design concept in this invention, such as adding multijet-orifices or adding spirals on the needle head or on the conical surface(C) of the nozzle body, these ramifications are within the scope of this invention.

DRAWINGS

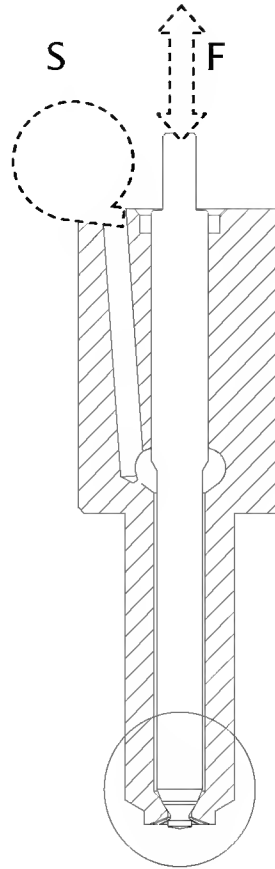


Fig. 1

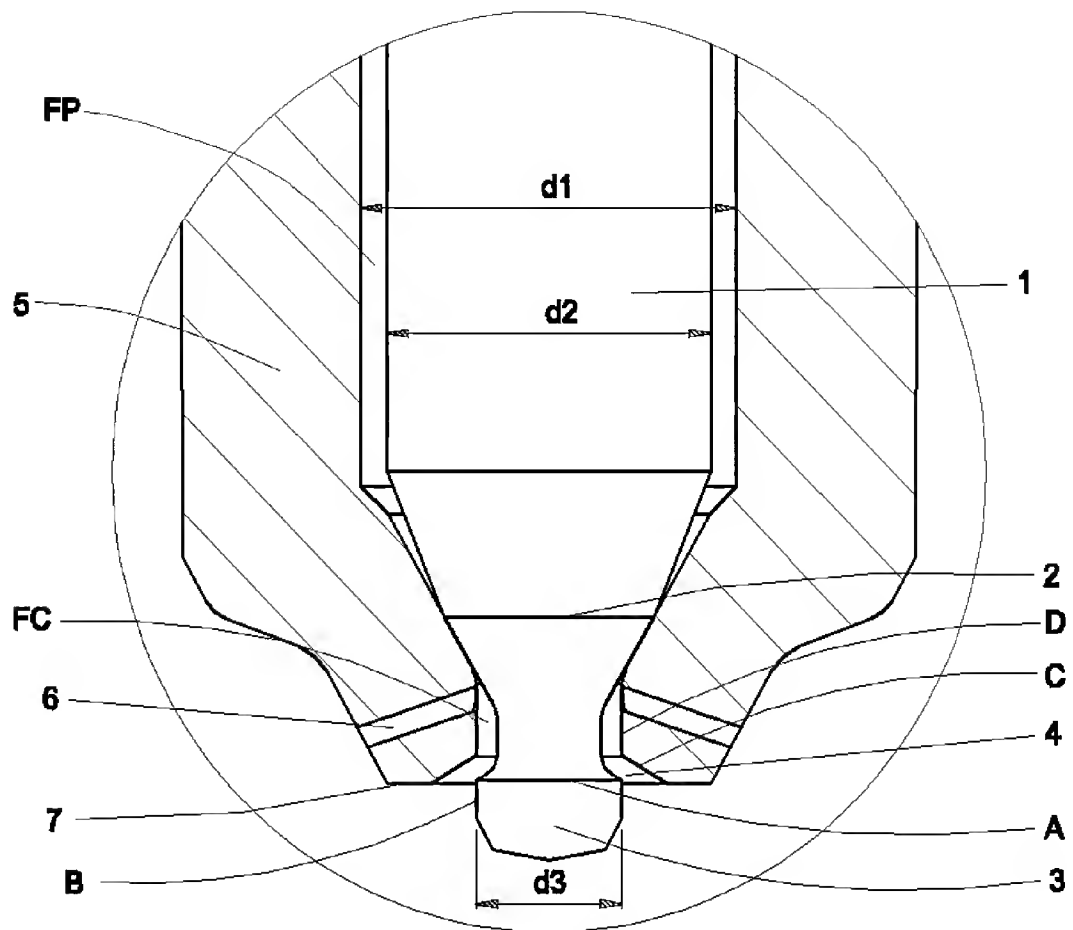
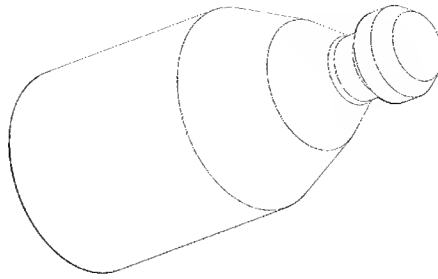
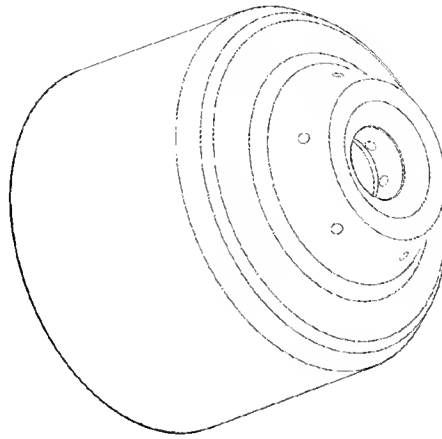


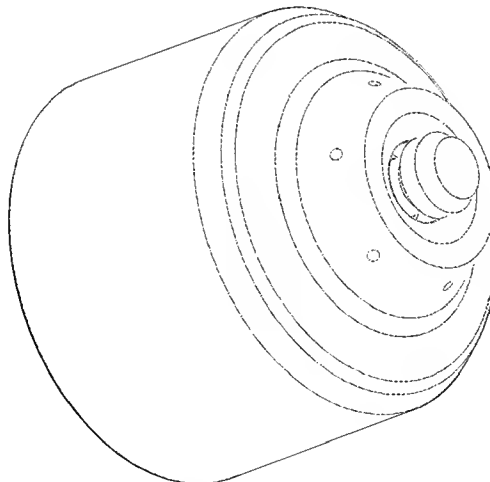
Fig. 2



(a)



(b)



(c)

Fig. 3

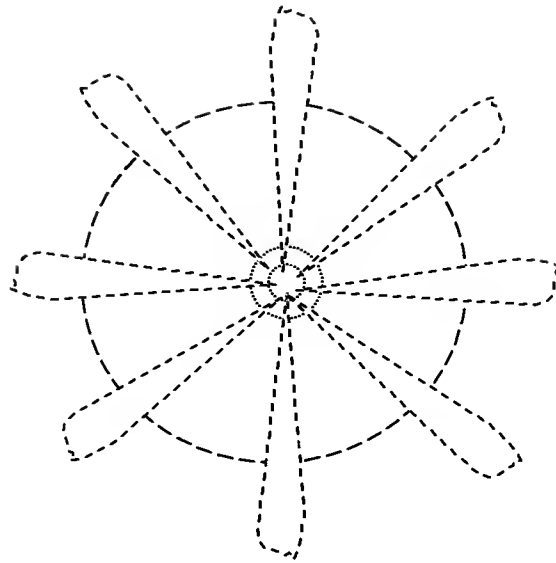


Fig. 4

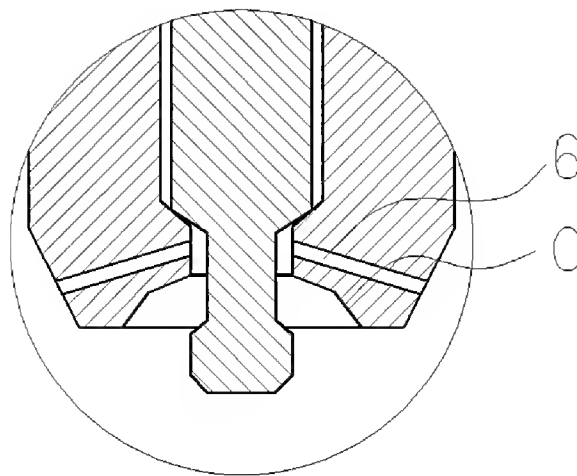


Fig. 5

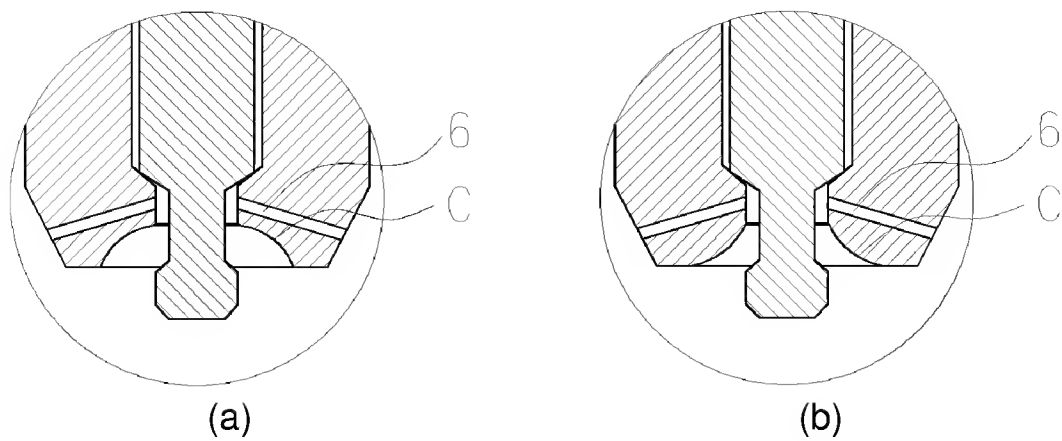


Fig. 6

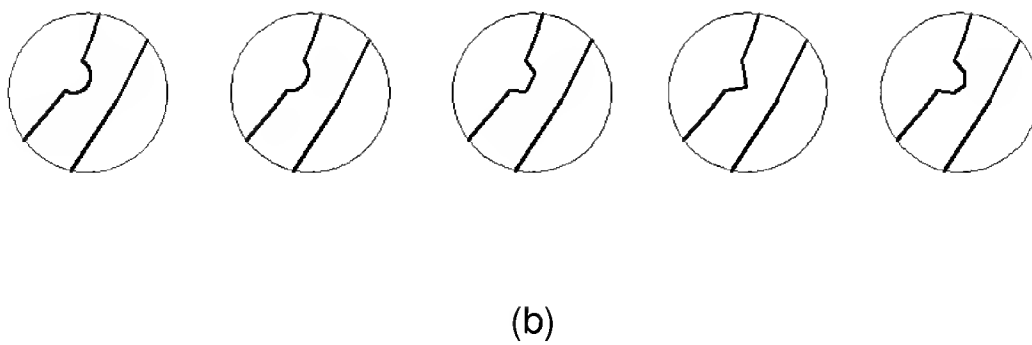
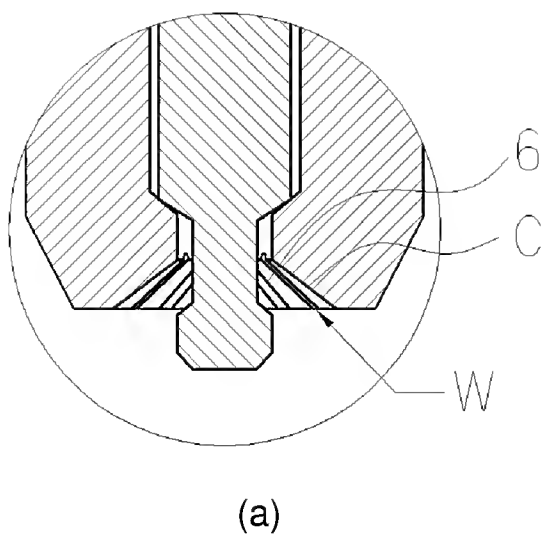


Fig. 7

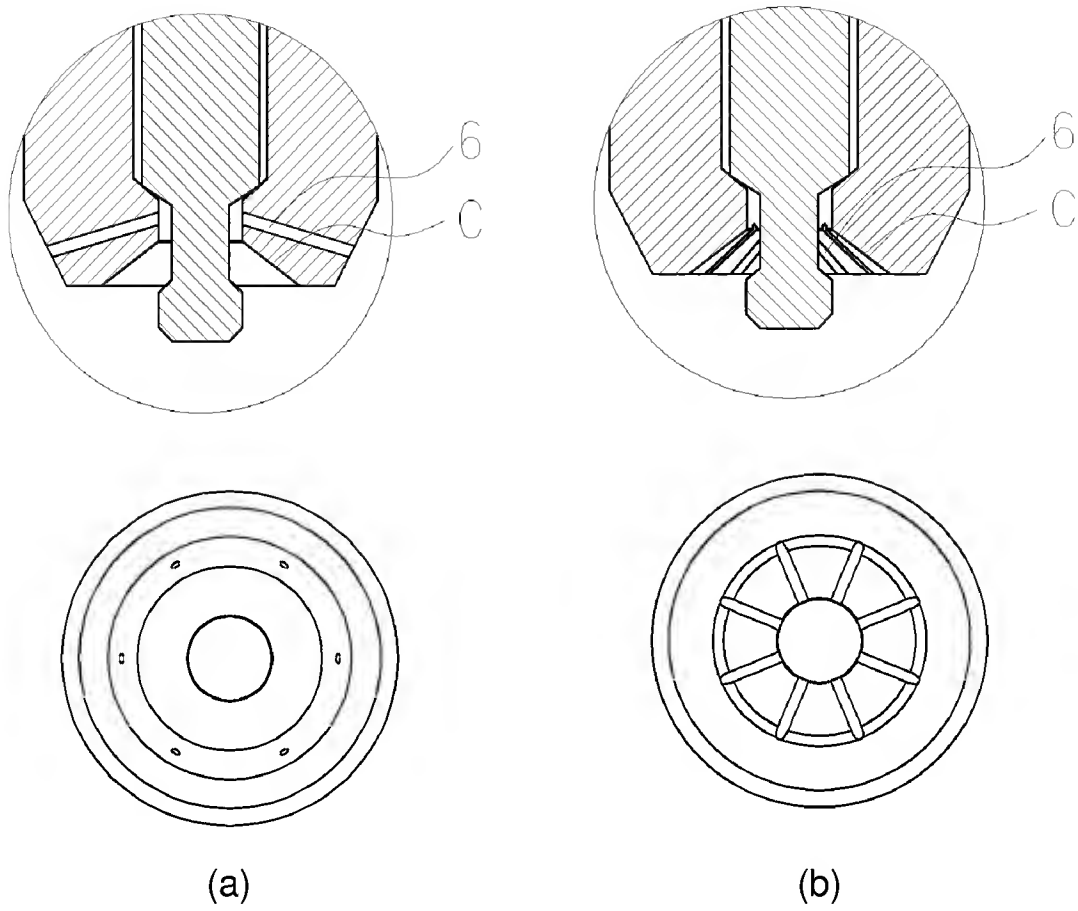


Fig. 8

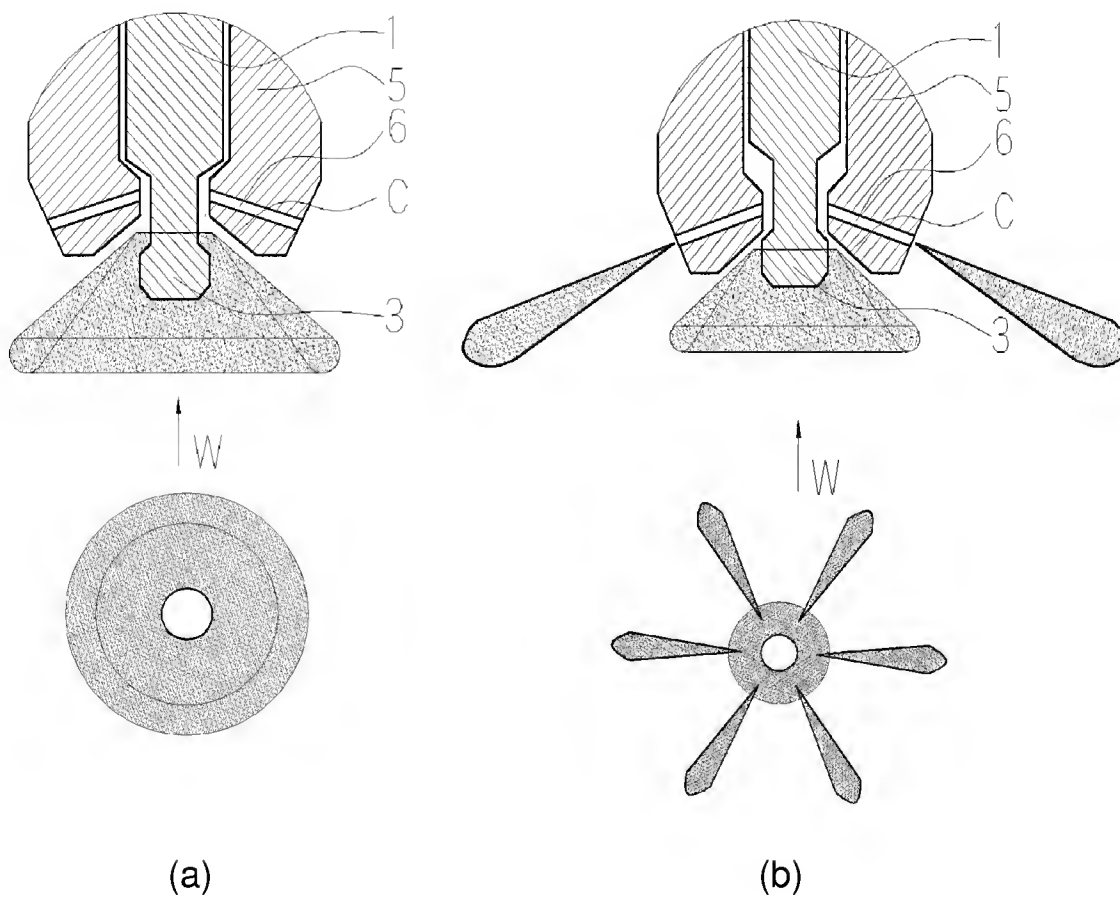


Fig. 9

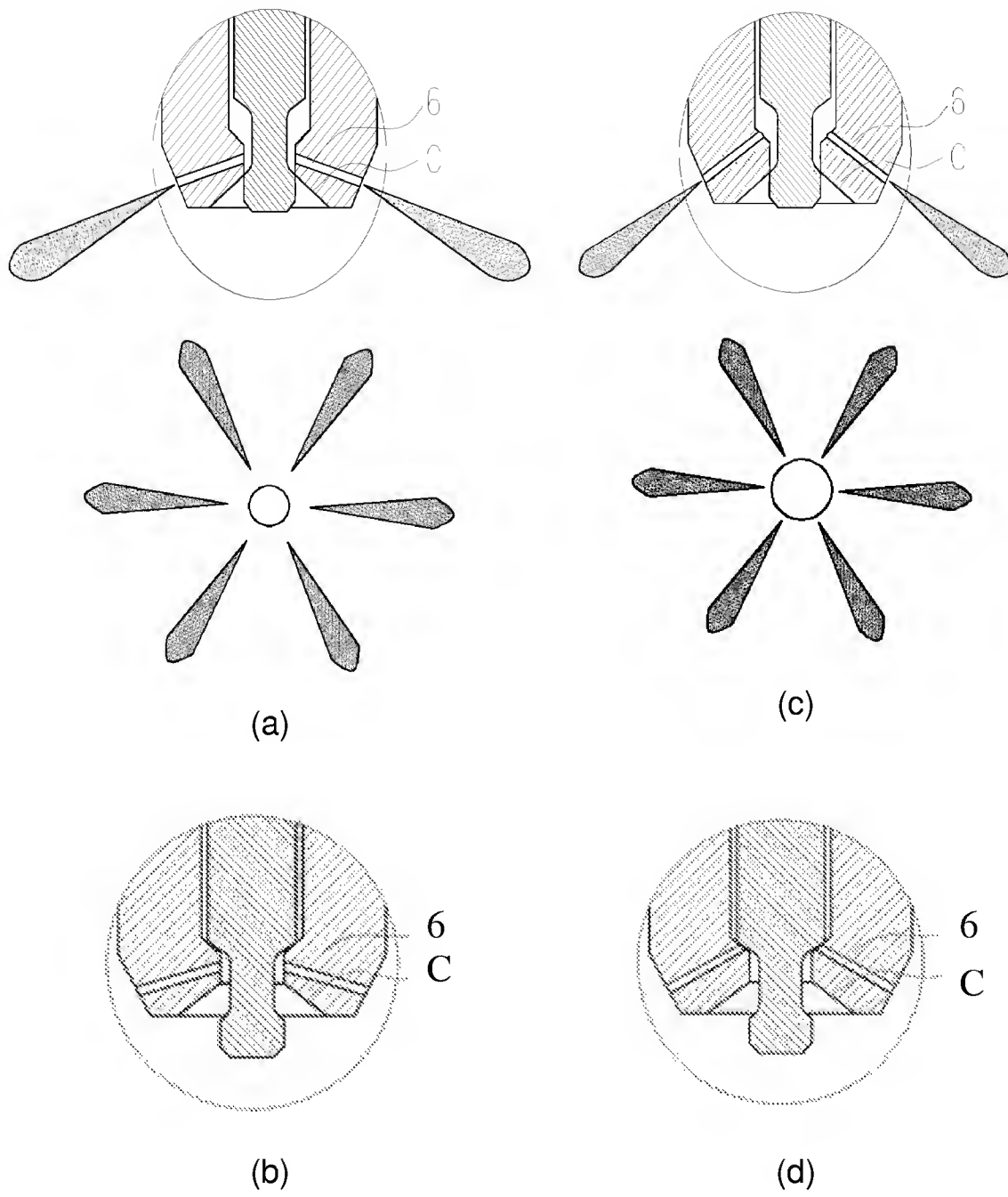


Fig. 10

APPEAL BRIEF

Drawings

1. Drawings are extended to address every features in claims.
2.
 - 2.1 The conical surface being a diverging curve surface of claim 5 is shown in FIG. 6;
 - 2.2 The conical surface with 2 conical surfaces of claim 4 is shown in FIG. 5.
 - 2.3 Plurality of multijet orifices being on the conical surface of claim 7 as well as the various orifice types (semi-circular, arcs, triangles, trapezoids, etc) Are shown in FIG. 7;
 - 2.4 The variable circular aperture of claim 15 is shown on FIG. 9 (a), the diagrams of flow during low to medium pressure (a) and flow during high pressure of claim 15 are shown in FIG. 9 (a) & (b), respectively.
 - 2.5 The diagrams for claim 13, where multijet-orifices (6) are distributed on or under the conical surface (C) so that they can be open channels (b) or closed channels (a) are shown in FIG. 8.
 - 2.6 The diagram of claim 14 is shown in FIG.10, in which a mixed-mode fuel injector has a plurality of multijet-orifices underneath the said conical surface (C), forming a sac-hole (FIG. 10a) or valve-covered-orifice multi-hole type (FIG. 10b) injector through blocking the circular aperture by the needle head at a predefined needle-lift range.

Response to Claim Objections:

3. Claim 11-12 are cancelled. Claim 13 is amended such that it *depends on claim 2 only*. Thus, no new matter is added, multiple dependent is removed.
4. Claim 19 is cancelled.

Response to Claim Rejections – 35 USC § 112

5. First paragraph of 35 U.S.C. 112.
6. Claim 17 is cancelled, so any confusions between claims 1, 2 and 17 would be eliminated. The applicant has two tele-conferences before with the Examiner and Examiner's supervisor. The technical contents for claim 1 & 2 has been clarified

and agreed upon as in interview documents. So the rejections for claim 1 & 2 based on 35 U.S.C. 112 should not be raised again

Applicant made presentation through web-teleconference and disclosed the differences in figure 5 of the Lambert vs. the applicant's invention. The applicant gave specific physical meanings of the micro-variable-circular orifice through a three dimensional assembly drawing. The applicant explained that the injector of Lambert cannot produce two different spray patterns of multiple jets and hollow conical spray. Applicant explained that the first needle lift of Lambert can only generate the multijet (spray) flow, but not the hollow conical spray flow as it did in applicant's invention. The applicant and examiners further discussed the mechanism of lifting the needle valve in applicant's invention while it closes the micro-variable-orifice in order to produce the different spray patterns.

The examiners agreed on with details presented for claim 1, the technical substances were clear and the differences from Lambert's invention were clear.

The examiners made following suggestions which the applicant agreed and were already incorporated in last amendment:

- Need clearly define the two-type of orifices, i.e., micro-variable-circular-orifice and conventional multijets orifices or passages, including the locations and compositions;*
- Need clearly define the two distinguished spray patterns (multijets and hollow conical spray) produced by the above two type orifices;*
- Need define the scenarios when flow is passing along one of the above orifices and both of the orifices;*
- Need add figures to illustrate nozzle body along, needle along, and assembly to more clearly illustrate the micro-variable-circular orifice;*
- Statements in specification can be revised under the condition of without adding new matters to make it more clear;*

7. Second paragraph of 35 U.S.C.112.

8. The inventions were clearly pointed out in claim 1, 2, 13, 14, 15, 16 and other claims. The Conical Surface (C) is clearly marked on FIG 2. The definition of this Conical Surface applies to all claims. There are two major design options for the multijet-orifices – that 'ON the conical surface' (C), as stated in claim 7, and is shown in FIG. 7 (a) & (b); that 'underneath the conical surface' (C), as stated in claim 13, 14, and is shown in FIG 8 (a), FIG. 9 (a) & (b), FIG. 10 (a) & (b). The

Examiner's interpretation of the conical surface being the needle seating surface (2) is not correct. The seal surface (2) is clearly marked in FIG. 2 and stated in claim 1, which is obviously different from the Conical Surface (C). The specific combination of needle lift magnitude and spray patterns, as stated in claim 1, 2, 15, 16, has not been disclosed in any previous art. They are the key inventions for this application.

9. Please refer FIG. 6. Such a curved surface (C) feature is not presented in previous arts. Thus Claim 5 is patentable.

Response to Claim Rejections – 35 USC §102

10. 35 USC §102 quotation as in the Office action document.
11. Claims 1-4, 5, 8, 14-16, 18 stands, they produce different spray patterns during the needle lift process. More specifically, in Date's design:
- Small needle lift – multijet spray;
 - Middle level needle lift – hollow conical – multijet spray;
 - Large needle lift – hollow conical spray;

In contrast, in Hou's 10/597,000 design:

- Small needle lift – hollow conical spray;
- Middle level needle lift – hollow conical – multijet spray;
- Large needle lift - multijet spray;

Also, Gate did not give any other designs such as multijet orifice ON the conical surface (C), Date did not give flow guide conical surface (C), Gate did not give a simple and smooth needle head curvature design as Hou did, as shown in FIG. 2.

Hou's design significantly improves the fuel injection adaptability and performance. In contrast, Date's design produces a spray pattern that is exactly what we want avoid in practical applications. Also, Gate's design has a section of guide (33) which is a significant concern of reliability for operation, since matching two surfaces(33 & 30 in Gate's FIG. 3) with small clearance in high speed needle open-closing operation is a very challenging task. In Summary, Hou's design significantly improves the reliability and capability for practical applications. Further, in Hou's design, the needle surfaces close to needle head are much simple and smooth curvatures which benefits guiding the fuel flow.

12. *What Simmons disclosed in U. S. Patent #3,042,317 is a mechanical puppet valve, which was manually activated by screws, it's a far different concept than Hou's invention disclosed here. Simmons's invention was related to an 'outward opening' valve, the sealing surface (15 in #3,042,317's FIG 1) is outside the nozzle body, which is completely different than Hou's invention, which is an 'inward opening' valve, and the sealing surface (2 in Hou's FIG 2) is inside the nozzle body.*

Response to Claim Rejections – 35 USC 103

13. *Since Hou's invention produce different spray patterns in different sequence than Date's invention, Hou's invention bears significant advantages for advanced combustion, as already discussed in above. It is not an obvious matter to change spray pattern varying sequence to fit for needs of advanced combustion. Thus, the rejections of claims 6,7,9-10 under 35 U.S.C. 103 (a) does not apply.*
14. *Claim 20 is canceled.*

The applicant has searched the related patents listed by patent examiner, and found none of the prior art can give variable spray patterns including a hollow conical spray and multijet spray, in the given sequence, through a single injector with a single needle valve as defined in the patent application 10/597,000. The applicant believes that the said injector is unique and bears inventions and merits not provided by prior arts, it's applicable for industrial applications.

Respectfully submitted,

/Deyang Hou/

May 21, 2011

Please recognize our Customer No. 45462